



Beyond climate change: The effects of deforestation on food security in the Lake Chad region

Christopher Ewuzie **Obianagwa**¹, Uchenna Paulinus **Okafor**², Louiemarie Adaeze **Ifem**³,
Onyinye Gift **Uwaechia**⁴ & *Chukwuemeka Chinedu **Ejiofor**⁵

^{1,3,5}Department of Political Science, University of Nigeria, Nsukka; ²Department of
Geography, University of Nigeria, Nsukka & ⁴Department of Political Science, Hezekiah
University Umudi, Imo State

*Corresponding Author: chukwuemeka.ejiofor@unn.edu.ng

Abstract

Deforestation of the Lake Chad region (LCR) has led to the loss of vegetation and biodiversity in the area. This situation has not only exacerbated the adverse effects of rising aridity in the region but has resulted in its desertification. Agricultural activities are endangered as a result of this unhealthy practice. Extant studies have largely focused on the nexus between climate change and food insecurity in the LCR without adequate attention on the impact of deforestation. The study examined how deforestation in concert with climate change has affected food security in the LCR. Data were generated from secondary sources and analysed using qualitative descriptive method. The theory of Anthropogenic Global Warming was adopted. The study found, among others, that the increasing deforestation of the LCR's vegetation is implicated in food insecurity menacing the area. It recommended, inter alia, an effective implementation of the African Union's Great Green Wall initiative aimed at ensuring strategic reforestation of the region in order to attenuate the adverse effects of climate change and restore the region's viability for agricultural production.

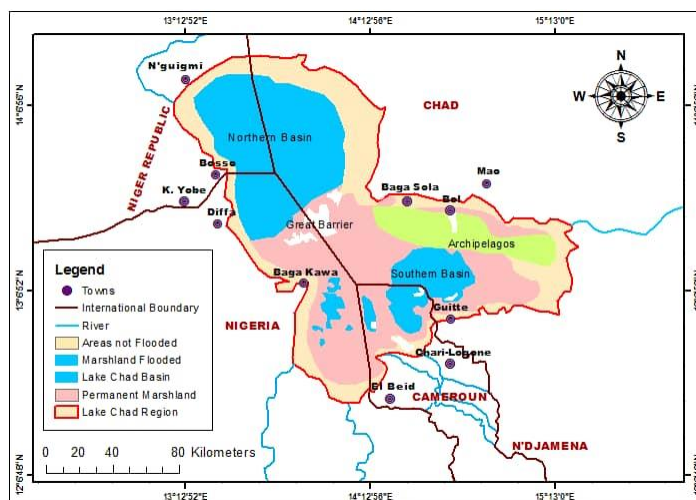
Keywords: Lake Chad region, climate change, deforestation, biodiversity, food security.

Introduction

The LCR is a geopolitical zone in sub-Saharan Africa which houses a strategic transboundary water formation known as the Lake Chad (LC). According to the International Atomic Energy Agency [IAEA] (2017), the LC occupies the eastern part of the Sahel at the southern wing of the Sahara Desert, covering a surface area of 2,381,000-kilometer square. The LCR is bordered by four countries, namely; Chad, Cameroon, Niger and Nigeria (see Figure 1) which constitute the pioneer members of the Lake Chad Basin Commission (LCBC), an inter-state organisation formed on the 22nd of May 1964 (under the Fart-Lamy, now N'Djamena Treaty) and is headquartered at N'Djamena, the capital of Chad. The LC and its ecosystem provides plains for both floral and faunal species (with about 44 species of medium and large-sized mammals including

elephants, and low savannah vegetation clustering along the lake's shores) making the ecosystem a dynamic complex (European Union (EU) & German Federal Ministry for Economic Cooperation and Development (BMZ), 2015). The LCR is also rich in liquid and solid mineral resources such as crude oil, salts, copper, iron ore, gold, etc. (Azo Mining, 2012), and is notable for some crafts including pottery, made from its available natural resources. The LCR's forestlands provide woods for the construction of shelters and boats, while baskets are made from the fibres found in the region. In recognition of its biodiversity, UNESCO is assisting the LCBC in its efforts to inscribe the LCR on the 'World Natural Heritage Site', and to identify certain sites in the region that could be established as 'biosphere reserves' (UNESCO, 2019).

Figure 1: The Lake Chad region



Source: GIS Lab., Department of Geography, University of Nigeria, Nsukka.

The LCR traditionally serves as a major route of socio-economic activities for the border communities and contributes largely to the national growth and development of all the countries that form its boundaries (Onamuti, Okogbue & Orimoloye, 2017). About 80 to 90 per cent of the LCR's population depend on agriculture (such as fisheries, herding and livestock, food crop farming, hunting, etc.) for their livelihoods (Food and Agricultural Organization of the United Nations [FAO], 2017). According to UNESCO (2019) and World Bank (2015), the LCR has high potential as it served as an important economic and cultural hub between sub-Saharan and North Africa for several decades, and played a key role in the food security of millions of inhabitants, two metropolitan centres which are N'djamena, the capital of Chad, and Maiduguri, the capital of Borno state in Nigeria. Despite the strategic importance of the LCR to human security and regional stability, some natural and anthropogenic factors have made it a dangerous environment. It has been noted that Lake Chad, its wetlands and resources have diminished by 70 per cent within the past 50 years but the population depending on the region and its surrounding ecosystem for their livelihood has increased from 3.5 million in 1960 to over 45 million inhabitants in 2020 (Kindzeka, 2021).

Consequently, food insecurity has become a major threat to the livelihood of millions of

people in the LCR. The region is reportedly one of the world's hotspots of extreme humanitarian crises (Ahiane & Moyo, 2021). A number of factors, including climate change and human insecurity, are blamed for this unprecedented food crisis in the LCR. In late 2017 alone, it was reported that more than seven (7) million people suffered from extreme food insecurity, while more than two (2) million were displaced following the intractable conflicts afflicting the LCR (Vivekananda, 2019). In the last three decades, droughts and reduced annual monsoons caused by global warming have worsened the hardship faced by riparian communities in the LCR. An increasingly changing climate characterised by variable rainfall patterns has resulted in the desiccation of LC and its surrounding wetlands. This has had adverse effects on the region's vegetation and its biodiversity. Corroborating this, the EU and BMZ (2015) reported that the northern region of LC is almost dry, while the southern part has recessed from its original size, and this resulted from the fluctuations in the annual inflow from the lake's tributaries.

Notably, studies have shown that the menace of increasing heat waves caused by global warming in the LCR is worsened by population pressure exerted on the region's resources (Dike & Dike, 2018; Zieba, Yengoh & Tom, 2017). Increasing urbanisation, expansion of human settlements and

unsustainable farming practices, among other factors, are considered to exacerbate the scourge of climate change in the LCR (Gundu, Adia & Aboh, 2014). Population pressure on the LCR has resulted in the overuse and misuse of the region's forest areas, thereby worsening its humanitarian crisis in concert with decades of unfavourable climatic conditions. On the other hand, insecurity and armed violence linked to the contending terror groups such as Boko Haram and the Islamic State of West Africa have also taken their toll on the current humanitarian crisis and inaccessibility of natural resources in the LCR. This no doubt affects the vulnerable population as well as their access to fresh water, grazing lands, fish stocks, farmlands and vegetation that residents depend upon (Vivekananda, 2019).

Meanwhile, the LCR member states, the LCBC and development partners such as the World Bank, FAO, UNDP and UNEP, among others, have undertaken measures to save the LC and its surrounding ecosystem through the inter-basin water transfer project and a roadmap for sustainable management of natural resources in the LC area. While several initiatives and projects have been undertaken by the LCBC and development partners towards addressing the adverse effects of climate change in the LCR, there are limited efforts from official publications and scholarly works towards mainstreaming the

effects of deforestation on food security in the LCR. In order to fill this knowledge gap, this paper undertook the assessment of the effects of deforestation on food security in the Lake Chad region. The study is organised into different sections. Section 1 is the introduction, while Section 2 deals with the conceptual clarification of climate change, deforestation and food security. Section 3 focused on the review of related literature, while Section 4 provided a theoretical explanation of the problem of the study. Section 5 presented the methodological requirements of the study, while Section 6 explored various factors driving deforestation in the LCR. Section 7 examined the effects of deforestation on food security in the LCR, while the study is concluded in Section 9, with recommendations made based on the findings.

Conceptual clarification of climate change, deforestation and food security

The history of attempts to contextualise climate change has been 'double-stranded' from scientific concern to public propaganda. Notwithstanding this, several definitions have been advanced in both official and scholarly publications to clarify the concept of climate change. The Intergovernmental Panel on Climate Change [IPCC] (2019) defined climate change as a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties

and that persists for an extended period, typically decades or longer. The National Aeronautics and Space Administration [NASA] (2021) stressed that the term climate change should not be confused with global warming as they have different meanings even though they are used interchangeably. While global warming refers to the long-term heating of the earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in the earth's atmosphere, climate change on the other hand is a long-term change in the average weather patterns that have come to define earth's local, regional and global climates (NASA, 2021).

Moreover, efforts have been made in the literature to clarify the term deforestation. For instance, the IPCC provided two perspectives aimed at defining deforestation. The first defines deforestation as the conversion of forestland to non-forestland, while the second defines it based on a decrease in the canopy cover or carbon density by a given amount or crossing one of a sequence of thresholds (IPCC, 2000). Van Kooten and Bulte (2000) defined the concept as the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development, among others. FAO (2007) identified comprehensive and defining facts about

deforestation as follows: there is a minimum threshold of 10 per cent for the exploitation of forest trees and vegetation; deforestation can be intentional (through human activities such as agriculture, urban development, etc.) or unintentional (through uncontrolled grazing, fire disaster especially in arid areas, etc.); deforestation is a long-term sustained loss of tree covers for over a period of ten (10) years. Interestingly, several empirical studies have identified deforestation as one of the factors that contribute to the problem of climate change (Gorte & Sheikh, 2010; Indarto & Mutaqin, 2016).

The concept of food security is multi-dimensional with many facets including agricultural production, trade of agricultural products and income, food quality, clean water, food hygiene, food governance, and others that influence an individual's or nation's food security. Thus, the concept of food security has evolved over time but gained prominence during the 1996 World Food Summit held in Rome. During this summit, a consensus on the meaning of food security was reached, and a general template for its definition was adopted. On this note, food security exists when all people, at all times and places, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996 cited in FAO, 2006).

From the clarification of climate change, deforestation and food security, it is clear that the interplay of climate change and deforestation will always produce snowballing effects on food security in any geopolitical location. Forests, from the dimension of forest function of climate regulation, play an essential role in food security. Conversely, the practice of deforestation increases the vulnerability of food production to climatic factors (such as low precipitation/monsoon, droughts, desert encroachment, etc.), the results of which are food insecurity, often characterised by crop failure, low agricultural outputs, food scarcity and shortage, as well as high costs of food stuffs, among others.

Literature review

The effects of deforestation on food security in the Lake Chad region

Deforestation is one of the indicators of measuring levels of ecological degradation in any geopolitical space. Scholars have impressed remarkably with studies bordering on the factors responsible for ecological degradations in the Lake Chad region (LCR) as well as their impacts on the livelihoods and food security in the region which is historically reputed for agriculture and itinerant trade. For instance, Riebe and Dressel (2021) examined various factors responsible for the shrinking of Lake Chad. They found that several interplays involving

declined rainfall, worsened by climate change, and human activity are implicated in the lake's dryness, which in turn impacts negatively on food security and livelihood in the LCR. In a related study, Ahiane and Moyo (2021) investigated climate change, human insecurity and conflict dynamics in the Lake Chad Basin. The study found that limited access to water, fertile land and pasture as a result of climate change undermined the livelihoods of the basin's vulnerable population, which in turn triggered recurrent conflicts in the LCR. Meanwhile, Nwilo, Olayinka, Okolie, Emmanuel, Orji and Daramola (2020) interrogated the impacts of land cover changes in northern Nigeria and the implications on the Lake Chad Basin. The study revealed a pattern of vegetation loss across the north-west and the north-east regions of Nigeria, including the Lake Chad area. Onuoha (2008) focused on the declining natural resources of Lake Chad as an empirical basis to analyse the nexus that could develop among natural resource diminution, livelihood and conflicts in the region. Also, Dim, Duhu and Ngwu (2022) examined the recurrent herder-farmer conflicts in the Lake Chad basin, the Nigerian government's responses and the consequences on food security in the country. The study implicated weak government' responses in the lingering herder-farmer conflicts in the Lake Chad area which in turn contributes to the food security crisis in the region.

From the review of the literature, we observed that scholars have made significant efforts to problematise the impact of climate change, establishing its interactions with sundry anthropogenic factors that account for the lingering and recurrent ecological degradation, human insecurity and humanitarian crisis in the LCR. However, there exists inadequate empirical documentation and systematisation of the nexus between deforestation and the rising food crisis in the Lake Chad region. Against this backdrop, therefore, the study examined the impact of deforestation on food security in the LCR.

Theoretical framework

Anthropogenic Global Warming (AGW) theory

The study adopted the AGW theory for an explanation of the nexus between climate change and human-induced ecological degradation (such as deforestation) and how they affect food security in the Lake Chad region. The AGW is a theory that provides an explanation about today's rising trends in the average temperature of the earth's atmosphere and attributes the cause to human industrial and agricultural activities. Since the mid-20th century, growing banks of data and improved climate models have implicated human activities and convinced most climate scientists that rising trends in anthropogenic emission of greenhouse gases are directly responsible for a rising trend in

atmospheric temperature (Intergovernmental Panel on Climate Change- IPCC, 2014). IPCC (2014, p.2) has stressed that "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history with widespread impacts on human and natural systems". Although some of these gaseous emissions are from natural sources (such as volcanoes), their overall emissions are regarded as insignificant by climate scientists when compared to the volume of gases emitted through industrial, transport and agricultural activities.

The intellectual debates that culminated in the development of AGW theory began in 1988 during the maiden meeting of the IPCC, a wing of the United Nations Development Programme (UNDP). The theory derives from the intellectual consensus that global warming is caused by the increasing concentration of carbon dioxide (CO₂) in the atmosphere resulting from the emission of greenhouse gasses. The theory, therefore, affirms that human influence on nature is largely associated with the warming of the atmosphere and ocean, changes in the global water cycle, reduction in snow and ice, global mean sea level rise, increasing heat waves and drying of water bodies in the arid regions. The IPCC observed that this human influence has grown extremely (likely 95 to 100 per cent) and has been the dominant

cause of the observed warming since the mid-20th century (IPCC, 2014; 1988).

Consequently, the key thesis of AGW theory provides a useful scientific basis for explaining the effects of climate change and deforestation on food security in the Lake Chad region. The AGW model enabled us to find a link between the natural and anthropological causes of ecological degradation in the LCR, as well as establish the basis for providing an empirical explanation of their impacts on livelihoods in the region. From the AGW worldview, the study deduced that the growing food insecurity in the LCR is not only caused by natural factors but also by the uncontrolled human exploitation of the region's ecosystem. All these contributed to water stress, decline of freshwater resources, land degradation, and desert encroachment. The net effect is productivity losses and the collapse of livelihood systems, resulting in food insecurity in the region.

Methodology

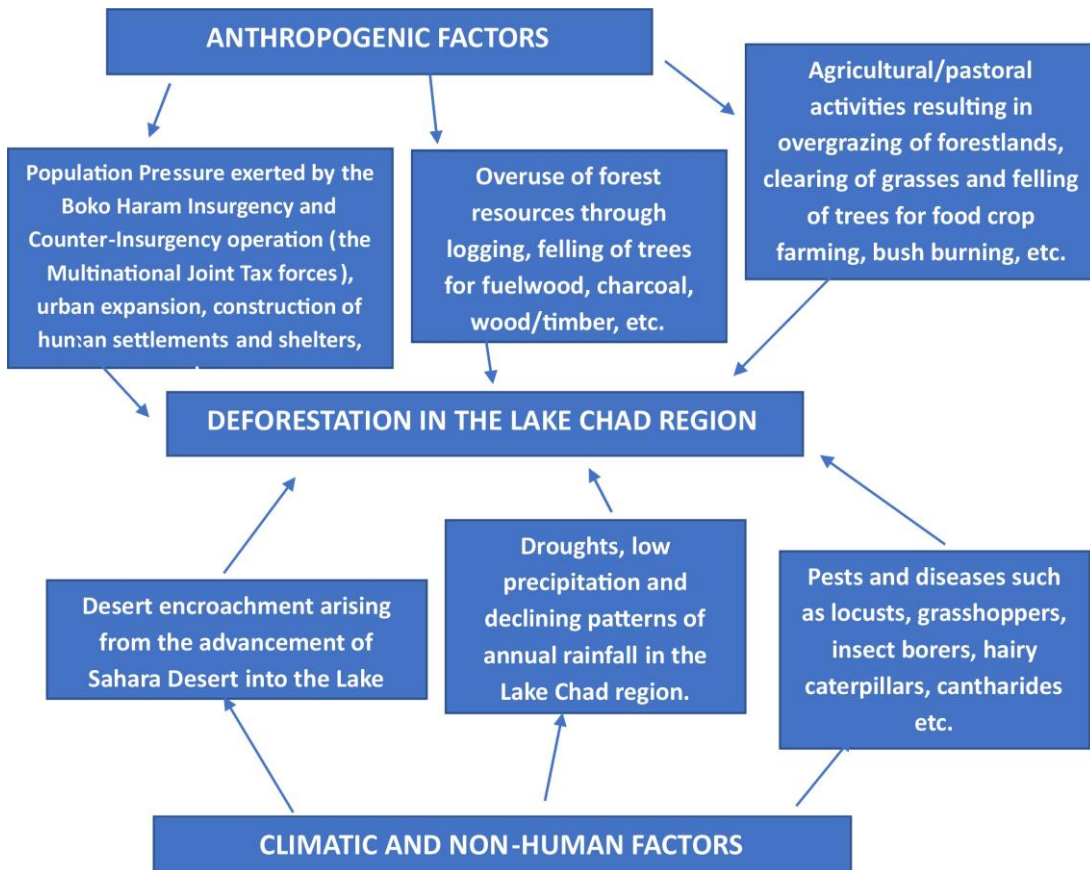
This section provided the research design as well as methods adopted for data collection and analysis. The study adopted an ex-post facto design, the justification being that those events that we observed (in this case, the effects of deforestation on food security

in the Lake Chad region) have already taken place. Consequently, "the effects of deforestation" became the unit of analysis for the independent (X) variable, while "food security in the Lake Chad region" was the unit of observation for the dependent (Y) variable. Therefore, our choice of ex-post facto research design is aided in data presentation and test of hypothesis. The study relied on the qualitative data collected through secondary sources involving official documents from the LCBC, FAO, AfDB, UNDP, World Bank, etc. and scholarly works, including journal articles, textbooks and unclassified documents, among others that are related to the problem of the study. Data collected were analysed descriptively using a qualitative descriptive method which enabled us to provide a detailed presentation, explanation and discussion of the findings of the study.

Drivers of deforestation in the Lake Chad Region

The spate of deforestation in the Lake Chad region has assumed various dimensions and patterns. Figure 2 below summarised various trends and indices of deforestation in the LCR.

Figure 2: Summary of indices of deforestation in the Lake Chad region



Source: Authors' creation.

Apart from the climatic and non-human factors intensifying desertification of the LCR (Lamprey, 1988; Dami et al., 2011), a number of anthropogenic (human) factors have been identified as drivers of deforestation in the region (Dike & Dike, 2018). Some of these unsustainable human activities causing the degradation of forestlands in the LCR include population pressure caused by increasing

urban growth and expansion (World Bank, 2002; Zieba, Yengoh & Tom, 2017; Dike & Dike, 2018), overuse and misuse of forestlands arising from overgrazing, harvesting of tree for fuelwood, charcoal, wood/timber, etc. and farming of food crops (EU & BMZ, 2015; AfDB, 2015; Zieba, Yengoh & Tom, 2017). Also, for nearly a decade, the LCR has become a theatre of war for the

Boko Haram Insurgency and Counter-Insurgency operations (United Nations Security Council, 2017), which has caused severe devastation and degradation of the region's forestlands and entire ecosystem.

As shown in Figure 2, multiple human factors have continued to aid deforestation in the LCR, one of which is agriculture. FAO (2010) and Youmatter (2020) have observed that agriculture (accounts for about 80 per cent of deforestation, with 33 per cent resulting from subsistence farming in developing countries) is the major driver of deforestation worldwide. Similarly, livestock production, which usually requires large areas of land, accounts for 14 per cent of deforestation globally (FAO, 2010). The statistics in the LCR shows that deforestation is menacing in the area. For instance, from 2000 to 2020, Chad, Cameroon, Niger and Nigeria lost 49.9kha, 708kha, 1ha, and 141kha of humid primary tree covers respectively- equivalent to 12 per cent, 48 per cent, 55 per cent, and 14 per cent decrease in tree covers (Global Forest Watch, 2022). Overexploitation of forestlands has impacted negatively on the LCR, especially in the past three decades of extreme temperatures and low precipitations. On this note, Dike and Dike (2018, p. 26) observed that "high rates of deforestation in the tropical rainforests of West-Central Africa shifted the rain-belt southwards, which resulted in the Sahel droughts; and that pressure from rapidly growing human and livestock populations exceeded the

carrying capacity of the Lake Chad ecosystem resources". This implies that the carrying capacity of the LCR has been outweighed by the number of herders and herds living and grazing in the region. An earlier study on the dynamics of desert and drought in the Sahel conducted by Charney (1975) showed that climate variability in the Sahel and LCR, in particular, is aggravated by the systematic and irreversible degradation and desertification of the zone through overgrazing and deforestation as well as inefficient land-use practices.

In the last decade, the number of crop and livestock farmers in the LCR has witnessed a rapid growth as a result of continuous reduction in the size of Lake Chad and its resources. These were former fishermen who left their hitherto fishing profession following the depletion of aquatic resources in the shrinking Lake Chad. This development tends to put more pressure on the region's eco-vegetation, as more forestlands are cleared for food production and grasslands overgrazed, while trees lose their cover, exposing the lands, the shallow lake, and its wetlands to extreme heat waves in the Sahel region. FAO (2009) observed that the wetlands of Lake Chad have continued to disappear due to drought, coupled with unsustainable human activities which have devastating effects on the flora and fauna community. Also, due to vegetation disturbance and overgrazing, grasses have become scarce in the LCR (EU & BMZ, 2015).

Following the droughts of the 1970s, Pandey (2017) noted that the LCR's restricted grazing pasture pushed herders to switch from raising cattle and camels to browsing animals, such as goats and sheep, further degrading the region's vegetation. In addition, FAO (2009) highlighted that excessive grazing on pasturelands in the LCR has resulted in deforestation and made the region's climate drier. Meanwhile, the species composition and plant cover density are also altered by overgrazing (Perkin & Thomas, 1993). In the Lake Chad basin, Dami et al. (2011) claimed that drought and desertification become imminent when vegetation, in particular, gets damaged or completely destroyed due to human activities, particularly grazing by animals.

Population pressure exerted by urban growth and expansion of human settlements is identified as one of the key factors fueling deforestation in the LCR. Table 1 below provides a projected population growth rate by surface area in the LCR. As shown in Table 1, the LCR's population was estimated at 27.9 million in the year 2001 and was projected to double by the year 2050. The demography of the LCR has witnessed a significant surge in the last decade. The World Bank (2002) estimated the region's population growth rate at 2.3 to 3 per cent annually, while the population density was calculated at 50 inhabitants per kilometre square (EU & BMZ, 2015).

In addition, an earlier report from UNESCO cited in Onuoha (2008) put the growth rates of the human population in the LCR at 2-3 per cent per annum and the real-time human population of the region at over 37 million by the beginning of the 2000s, with more than 50 per cent of this domiciled in the Nigerian side of the region. Notwithstanding variations in the estimated population growth rates of the LCRs, what seems to be more fundamental is that unchecked human migration into the region, coupled with the increasing socio-economic activities such as fishing, livestock grazing and browsing, have escalated the ecological degradation of the forestlands and ecosystem of the LCR (Dike & Dike, 2018). This implies that vast areas of land hitherto used for agriculture are being cleared and converted to permanent or temporary shelters. Notably, Obianagwa (2017) stressed that while Lake Chad is rapidly receding, increasing urban growth has resulted in the reclamation of lands for other purposes, with camps converted to permanent settlements. Beyond the negative effects of natural climate variations, population pressure resulting from rapid population growth as shown in Table 1, is identified by scholars as a key factor driving the overuse and misuse, overexploitation and degradation of LCR's ecosystem including its forestlands (Ngatcha, 2009; Dike & Dike, 2018).

Table 1: Projected population growth by 2050 and surface area of Lake Chad region

	Cameroon	Chad	Central African Republic	Niger	Nigeria	Total
Population in 2001	2,671,200	6,428,056	890,400	305,280	17,648,832	27,943,768
Estimated population by 2050	5,288,976	12,727,550	1,762,992	604,454	34,940,687	55,328,659
Surface area (km ²)	56,800	361,098	197,800	231,325	205,500	1,052,523

Source: Culled from Ngatcha (2009).

Other subtle ways the Lake Chad forestlands are degraded as shown in Figure 2, include indiscriminate cutting of trees for wood, fuelwood and charcoal, as well as bush burning usually witnessed during dry weather and extreme temperatures. Logging or reckless felling of trees is a catalyst for forest degeneration. Firewood gathering is also growing as a means of livelihood among women, and its trade is gaining strongholds in the LCR. The lucrative nature of this trade on fuelwood as an alternative source of income has increased pressure on the forest reserves, thereby making the region's ecosystem more vulnerable to climate change. This strips the vegetation covers and exposes the ecosystem to high aridity. Nagarajan et al. (2018) and Vivekananda et

al. (2018), in a Climate-Fragility Risk Assessment Project, stated that deforestation in the Lake Chad basin is driven by firewood consumption for cooking. Also, the African Development Bank (AfDB) President, Akinwumi Adesina, during the 2015 African Ministerial Conference on Environment (AMCEN), stressed that about 75 per cent of deforestation in the LCR is due to charcoal burning (AfDB, 2015). Again, the LCR is regularly invaded by crop-devouring pests (such as locusts, grasshoppers, insect borers, hairy caterpillars, cantharides, seed-eating birds, rodents, diseases and weeds), causing not only a substantial deforestation of the region but a drop in yields (AfDB, 2010). Specifically, the AfDB (2010) observed that

pests alone cause losses of up to 50 per cent of production and vegetation in the region.

In a study of seasonal migration and settlements around the LCR, Zieba et al. (2017) observed that the increasing population in the lake region is compounding pressures created by a shrinking Lake Chad. Aliyu et al. (2014) also asserted that deforestation is escalating the problems of environmental degradation and loss of biodiversity in the forestlands of LCR. Moreover, Okanla (2020) linked deforestation to poverty; and observed that disadvantaged communities in sub-Saharan countries need land for small-scale farms as well as firewood and charcoal. This partly informed the finding that poverty and overpopulation account for greater incidents of forest loss (FAO, 2016).

Interestingly, Boko Haram insurgency and counter-terrorism operations have also caused extensive physical damage to the LCR's forestlands. For the past decade, the region has been a theatre of warfare between the Boko Haram terrorists and the Multinational Joint Taskforce (JTF) led by the Nigerian military. According to FAO (2017), Boko Haram-related violence has adversely affected countries of the LCR, and has disrupted agriculture and other socio-economic activities, causing a humanitarian crisis in an area already plagued by food insecurity, poverty and environmental degradation. This has resulted in the

destruction of vegetation and devastation of the region's ecosystem, increasing its vulnerability to desert encroachment. The ongoing conflict has disrupted the entire spectrum of humanitarian activities and livelihoods in the region. Following this crisis, food insecurity increased from 19 per cent in early 2016 to 39 per cent a year later in Adamaoua (a Cameroonian territory) part of the Lake Chad region (Comolli, 2017). Massive population displacement as a result of the insurgency further contributes to deforestation in the region. One of the few ways that displaced populations can make money to support their families is by cutting down trees for sale, but this has a terrible impact on the ecosystem of the region.

The effects of deforestation on food security in the Lake Chad region

This section discussed the impact of deforestation on food crops and livestock production, as well as wildlife and hunting in the LCR.

The impact of deforestation on food crop production in the Lake Chad region

Food crop production is considered the main socio-economic activity engaged by more than half of the population residing in the LCR, with the area of cultivated land estimated at over 2,800,000 hectares (EU & BMZ, 2015). These are distributed among the region's member states in Table 2 below as follows:

Table 2: Cultivated land areas in the Lake Chad region

Lake Chad regions	Cultivated land areas
Chad	125.000 hectares
Cameroon	44.500 hectares
Niger	2.010.000 hectares
Nigeria	560.000 hectares

Source: Compiled by the authors from the European Union and German Federal Ministry for Economic Cooperation and Development (2015).

While there are many food crops produced in the Lake Chad region, the cultivation of cotton, rice, peanuts, maize, wheat, millet, rice, potato, melon, tomato, capsicum, garlic, onion and others dominate cash crops production in the LCR. According to EU and BMZ (2015), crop farming largely for the subsistence of the inhabitants in the LCR is faced with severe problems arising from desert encroachment and loss of vegetative covers due to deforestation in the area. Drier soil, the disappearance of forest vegetation and diminished soil nutrients often result in crop failures and poor harvests. Destruction of ecosystems and conflicts which worsened the effects of climate change in LCR pose serious sustainability problems for agricultural activities in the region. Thus, ecological degradation caused by deforestation and desert encroachment in the LCR, in turn, impacts negatively on cash crop production and subsistence-based livelihoods of the people living in the region, degrading regional food security and quality of life (World Food Programme, 2016).

Consequently, the annual growth rate of farming in the cropland areas of LCR declined to 0.42 per cent from 1992 to 2001, to 0.31 per cent during 2001 to 2010 and 0.03 per cent during 2010 to 2019 respectively (World Bank, 2021).

The impact of deforestation on livestock production and animal browsing in the Lake Chad region

Importantly, the grass and forest areas of the LCR are known for an economy of scale for livestock production and animal browsing. This was estimated to value more than 286 billion CFA francs (EU & BMZ, 2015). Besides an income source, rearing of livestock and bovines such as camels, horses and donkeys not only aids in farming activities but also provides means to local transportation of both humans and goods across the arid Sahel and LCR in particular. As shown in Table 3 below, the population of livestock predominantly reared in the LCR includes cattle, camels, goats and sheep, among others.

Table 3: An estimate of livestock population in the Lake Chad Basin

Animals	Population
Cattle	4,571,453
Sheep	Unspecified
Goats	7,401,392
Camels	153,700
Horses	Unspecified
Donkeys	Unspecified

Source: Compiled by the authors from EU and BMZ (2015).

However, as the menace of deforestation continues to ravage the forestlands and grazing areas of LCR, and with over-grazing and increasing pressure on already low moist soil by the competing farmers, animal production becomes severely plagued in the region. This has resulted in the death of animals due to starvation, malnutrition and diseases. It has also led to the migration of livestock farmers and animal breeders to more ecologically friendly locations or a change of livelihoods. On the other hand, while the grasses and vegetative covers are disappearing due to the combined effects of deforestation and climate change, the flocks of cattle, horses, camels, donkeys, sheep, goats, etc., continue to strip the region's ecosystem of its remaining vegetation. The livestock population has continued to increase over the years in the LCR more than the region's forage capacity can support. For some cash crop farmers in the Lake Chad area, the lands are becoming drier and

infertile, with fewer prospects for food crop production, and to survive and sustain their livelihood, they convert to browsing animals in the region. According to Zieba, Yengoh and Tom (2017), the precarious nature of the ecosystem in the LCR became visible in the 1950s and 1960s when the balance was altered by the settlement of pastoralists and the expansion of agriculture into the herders' grazing lands. According to them, this resulted in the rapid growth of human and livestock populations which in turn elicited a loss in the land's productivity from overgrazing and the intensive cultivation of cash crops.

Thus, deforestation in the LCR is driven by two factors: first, by the cash crop farmers who are clearing more and more of the forest and grazing lands to produce more food for both subsistence and commercial needs, and second, by the increasing population of livestock in the region with more people

engaging in animal browsing, leading to instability of the region's ecosystem. Consequently, both livestock and cash crop production are facing regression and have become unsustainable in the LCR. This is evident in the rising indices of mortality, diseases and malnutrition among the livestock community, as well as low productivity of cash crops subsector. This has limited the productivity of livestock and crop farming in the region (World Bank, 2021). Furthermore, with the disappearance of shorelines, wetlands, grass and forest lands which hitherto supported forage growth for the livestock, the livelihoods of livestock farmers have become endangered. According to FAO (2022), the degradation of pasturelands in the LCR has resulted in the shortage of dry matter for forage at an estimated rate of 46.5 per cent, leading to a reduction in the livestock population and biodiversity threat. Notably, Zieba, Yengoh and Tom (2017) argued that the combined effects of overgrazing, unsustainable food crop farming, loss of vegetative cover, land degradation, a decline in soil fertility and deterioration of pasturelands culminate in a fall in agricultural productivity and household incomes in the LCR.

In addition, deforestation intensifies desertification of the LCR and has adverse effects on pastoral agriculture as many livestock and bovines either get malnourished due to shortage of pastures, dehydrated due to water stress and hot weather or die as a

result of a combination of these factors. Part of the consequence is that Chad and other vulnerable countries bordering the LCR have continued to struggle in the face of ecological degradation that threatens its nomadic community, thereby causing seasonal southerly migration by pastoralists and their herds (Jennings, 2019). The desiccation of pastures and essential wetlands in the LCR endangers the practice of pastoralism, thereby threatening the survival of the livestock economy and forcing many pastoralists to change the type of livestock they were raising, from grazing animals like cattle and camels to browsing animals like sheep and goats (Owonikoko & Momodu, 2020). In the same vein, pastoralists and their herds are advancing to the areas once occupied by Lake Chad, where the land proves to be quite fertile, thereby increasing pressure on available fertile land (Kitoto, 2016; FAO, 2017; Owonikoko & Momodu, 2020), and generating conflicts with crop farmers.

The overexploitation of forestlands and the decimation of grasslands across the LCR have become the key drivers of the decline in livestock productivity and migration of pastoralists to other locations of the region with less climatic variability. This has an impact on the region's population, already facing precarious livelihoods and difficult access to essential resources following the shrinking of Lake Chad and wetlands in the LCR (Vivekanand, 2019). Social tensions rise,

and there is likelihood of violent conflict arising when various groups, such as herders and crop farmers, fight for limited natural resources (Onuoha, 2022; Mbaye & Signe, 2022). Following this humanitarian crisis, Vivekanand (2019) stated that more than 7 million people have suffered from severe food insecurity and more than 2 million people are displaced from intractable conflict plaguing the LCR.

The impact of deforestation on the wildlife community in the Lake Chad region

The Lake Chad region has a huge diversity of plant and animal communities. The region's faunal species include diverse communities of wildlife such as red-fronted gazelle, dama

gazelle, dorcas gazelle, monkeys, hyenas, cheetahs, caracal, wild dogs, elephants, otters, hippopotami, kub, rodent species, giraffe, lions, tigers and others (EU & BMZ, 2015), which support the livelihoods of local hunters in the LCR. The present state of ecological degradation in the LCR is considered to have a profound effect on the local biodiversity through the loss of habitats, death and migration of endangered wildlife communities (EU & BMZ. 2015). The biodiversity of faunal species is facing a continuous threat of extinction in the LCR as a result of the loss of habitats. Table 4 below provides the list of wildlife species that are highly endangered following the spate of destruction of natural habitats and ecological degradation in the LCR.

Table 4: Wildlife species endangered by deforestation and loss of habitats in the Lake Chad region

Names of species	Status of species
African elephant	Endangered and significantly reduced
Antelopes	Endangered
Caracal	Highly endangered
Cheetah	Highly endangered
Crocodile	Endangered and significantly reduced
Crowned crane	Endangered and significantly reduced
Dama gazelle	Endangered
Dorcas Gazelle	Endangered and significantly reduced
Giraffe	Highly endangered
Hippopotamus	Endangered and significantly reduced
Kub	Endangered
Kuri cattle	Endangered and significantly reduced

Lions	Endangered and significantly reduced
Otter	Highly endangered
Red Monkey	Endangered and significantly reduced
Red-fronted Gazelle	Endangered and significantly reduced
Rodents	Endangered
Sitatunga	Highly endangered
Striped Hyenas	Endangered and significantly reduced
Tigers	Endangered and significantly reduced
Wild dogs	Endangered and significantly reduced

Source: Compiled by the authors from the European Union and German Federal Ministry for Economic Cooperation and Development (2015).

Consequently, the loss of habitats through deforestation, de-vegetation, land degradation, bush burning, over-grazing and reckless exploitation of forest resources in the LCR contribute adversely to the decline of wildlife in the region. The death of herbaceous plants, grasses and trees has grossly altered the floral and faunal community in the LCR. Notably, the LCR served as a historical host to regional biodiversity with an estimate of about 44 species of medium and large-sized mammals, as well as migrating birds found in the basin (UNESCO, 2019). UNDP (2002) stressed that over 370 species of birds alone are documented to find habitat in the LCR. Many of these birds have become endangered species and have either died or migrated following the disappearance of vegetation which before now provided them covers for shelters, nest formation and breeding. Some

of the wildlife once supported by LCR has also been decimated. Ayuba (2011) maintained that deforestation, agricultural expansion, reductions in soil fertility, heavy hunting and overfishing, among others, are responsible for the loss or deterioration of the habitats that are essential to the survival of wildlife. These alterations in the LCR's ecosystem and its vegetation have had a harmful effect on birds and mammals (EU & BMZ, 2015). With deforestation and desert encroachment, certain bird species are endangered, considering the significant reduction of their nesting habitats and wintering locations. As shown in Table 4 above, the loss of habitats contributes immensely to the reduction in large mammal species (namely African elephants, Kuri cattle, hippopotamuses, red-fronted gazelles, antelopes, hyenas, cheetahs, and caracals, among others) in the LCR. While some of

these animals have become savage in the region, others are highly endangered by desert encroachment and ecological degradation.

Consequently, the ecological degradation, loss of vegetative cover and destruction of natural habitats in the LCR have contributed to the deaths and disappearance, displacement and de-population of wildlife communities in the region. In the same vein as livestock farmers, the livelihood of hunters in the LCR has become endangered following these distortions in the region's forestlands and vegetation, which hitherto provided habitats and forage for the region's herds and wildlife.

The effects of these humanitarian crises on the dependent population are huge. For instance, the northern part of Nigeria (accounting for about 43 per cent of its total land areas) bordering the LCR loses over 350,000 hectares of arable lands to desertification per annum, and about 50 million people are vulnerable to food insecurity in these desert frontline states (Azare et al. 2020). The situation is the same in Niger and Chadian areas bordering the LCR. According to a report by the Africa Development Bank (AfDB), all Lake Chad basin countries are to varying degrees impacted by the degradation of the lake's productive ecosystems brought on by natural variability in the lake, climate change, and human activity. This is because more than 50

million people in the area now live in unstable and increasingly vulnerable conditions (AfDB, 2014). Similarly, the FAO estimates that in the LCR, which includes portions of Cameroon, Chad, Niger, and northeastern Nigeria, about seven million people run the risk of experiencing extreme hunger (FAO, 2017). The report further stated that unsustainable agricultural, livestock and fishery practices in the LCR are linked to price increases in agricultural inputs and food, loss of incomes, and limited food access and availability in the region.

The menace of food insecurity and loss of livelihoods in the LCR is glaring with stunning statistics of poverty, hunger and malnutrition, low incomes and migration among the riparian communities. According to the FAO 2017 report on the humanitarian crisis in the LCR, there are 6.9 million people who are severely food insecure, 515,000 children who are severely acutely malnourished, 2.5 million people who are displaced (the second largest displacement crisis in the world), 75.7 per cent of persons who are internally displaced are still living in host communities (increasing their vulnerability), and 1 million people who have returned home (FAO, 2017). Meanwhile, several indicators of underdevelopment in the LCR were discovered by Nagarajan et al. (2018), including low levels of schooling, high levels of poverty, low levels of national integration, as well as actual marginalisation.

Conclusion and recommendation

In sum, deforestation has contributed to food insecurity, depletion of biodiversity and loss of livelihoods for the local communities living in the Lake Chad region (LCR). In addition, it has weakened and degraded the soil, leading to wind and soil erosion. The net effect is that deforestation has undermined the stability of the ecosystem, which is critical to livelihood sustenance and food security. The findings of this study showed that deforestation, in concert with climate change and conflicts, is responsible for the worsening ecological degradation, desert encroachment, low crop and animal productivity, loss of livelihoods, displacement of people and animals, as well as depletion of wildlife and biodiversity in the LCR. To reverse the current

trends and improve the livelihoods of communities bordering the LCR, the following recommendation is made.

There is a need for strategic planting of trees and grasses within the LCR in order to protect the lake and other islands from the extreme heat in the Sahel region. This calls for enhancing forest governance of the LCR through effective implementation of the African Union's Great Green Wall of the Sahara and Sahel. This will ensure massive reforestation and strengthen the resilience of the region's natural ecosystems, thereby restoring the region's biodiversity and improving the living conditions for local populations, which will result in restoring the area to a paradise for fauna and flora.

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